# LAND-USE CHANGE DETECTION THROUGH REMOTE SENSING - A CASE STUDY OF MAMLAY WATERSHED OF THE SIKKIM HIMALAYA

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*Abstract.* This study has been carried out in the Mamlay watershed of South Sikkim using the satellite data from indigenous earth resources satellites IRS 1A/1B. The temporal changes have been analysed over the years 1988 and 1992. This set of multidate satellite data yielded spatial changes in land-use classes. The percentage variation at level I within significant classes were — Agricultural land by 52.5%, Forest land by −10.9%, Wasteland by 10.64% and Water bodies by −10.45%. The details of sub-classes at level II have also been worked out and presented. The scope of this study is outlined as an aid to the development of watershed management options.

## INTRODUCTION

Sikkim state of India comprises of mountainous terrains spread over 7096 sq.km. and is a part of the Upper Teesta basin. The main tributary of the Teesta river is great Rangit river. Zemu glacier feeds the Teesta river and the Rangit river is fed by snows of the Narsing and Kabru peaks. The rainfall in general is very high in Sikkim. The significant land-use categories of Sikkim are forest, pasture, barren, culturable waste and agriculture lands. In the context of mountain environment, watersheds are considered basic resource units. For a rational utilization of the land and water resources, a thorough analysis of watersheds is necessary. The present study had been undertaken as an aid to the management approach evolutions for Mamlay watershed of the South Sikkim district (Fig.1). It falls within the geographical co-ordinates 27°12'3"N to 27°16'14"N and 88°19'2"E to 88°23'30"E. This watershed encompasses a good profile of altitude, ethno-culture and land-use with majority of the inhabitants depending on agriculture (Sharma *et al.* 1992). The impacts of development in terms of economy, environment, micro-climate, vegetation, soil and topography etc. are noteworthy in this anthropogenically vibrant watershed. The principal human influences affecting the pattern, amount, and intensity of surface water run-off, erosion and

sedimentation are the varied land-uses and manipulations of surface water. The utility of remote-sensing data for land-use change studies have been demonstrated by other workers also (Dhinwa 1992; Hilwig 1982). Therefore, land-use change detection studies have been carried out for a period spread over 4 years from 1988 to 1992 which has yielded encouraging results. Satellite imageries of IRS 1A/1B pertaining to these years have been utilised for this in conjunction with primary and secondary data, Survey of India toposheets and field surveys. This study has been carried-out with the following objectives: (i) For establishing the land-use/land cover of this watershed using remote-sensing techniques for understanding their spatial distribution pattern, per cent and area under each class. (ii) For developing an approach for monitoring and detecting land use change over different years from multidate satellite data.

### Terrain Features

The Mamlay watershed area is characterised by the folded structure and the significant thrusts here are Sikkip and Tendong. Two major rock formations namely the Damuda and Daling are found here showing different levels of weathering and erosion (Sharma *et al.* 1992). The elevation range of the watershed is from 300 m near Rangit river in the west to more than 2500 m near Tendong
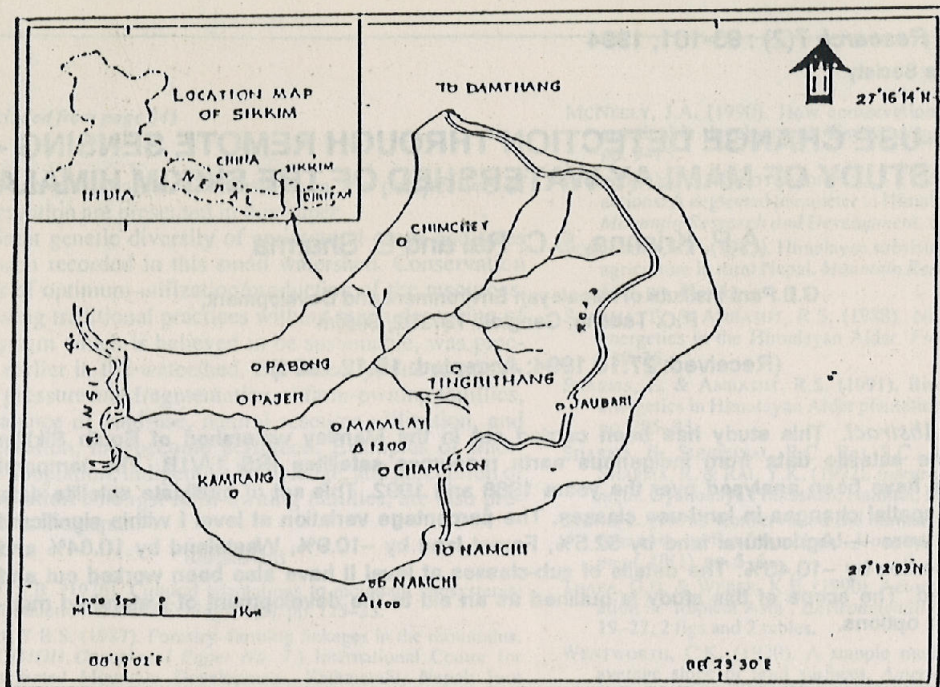
FIG. 1 Location Map of Mamlay Watershed of Sikkim



Plate 1. IRS LISS II FCC, November 1992 covering Mamlay watershed

peak in the north-east ridges. Rangit tectonic window forms one of the most important structural elements of this watershed. This watershed is the catchment area of Rangit river and has five perennial streams within it. The slopes show a range of 30° to 40°. Climatewise, there is a great microclimatic variation present in this area. It experiences high rainfall in the temperate region and has shadowed rainfall in the valleys of sub-tropical region. There is great diversity in vegetation types (Rai 1994) depending on the micro-climate, soil types, lithology, slope aspects and altitude within the watershed (Rai et al. 1994).

## METHODOLOGY

Land-use/land cover mapping of the Mamlay watershed has been done using multidate satellite data of IRS 1A/1B aided by other conventional data. Plate 1 shows IRS LISS II FCC of November 1992 covering this area. Ground check studies were also carried out for verifying image interpretations for each theme. Subsequently, these informations were transferred to the base map and final thematic maps were generated. Informations on various features derived from satellite and collateral data were integrated and analysed. The schematic steps of this study are depicted in the flow diagram (Fig 2). IRS 1A/1B LISS-II A2, Geocoded false colour composites (FCCs) of bands 2, 3 and 4 of 25 November 1988 and 27 November 1992 corresponding to Path/Row - 19/48 on 1:50,000 scale were used. LISS II data were used for this study as it has higher spectral separability than LISS I(Dadhwal 1988). The Survey of India Topographical map (78 A/8) on 1:50,000 scale was used as collateral data.

Visual interpretation of the multidate satellite data has been done using standard interpretation techniques (Sabins 1987) for extracting various land-use/land cover classes from IRS imageries. This was aided by ground-truth surveys for cross-checkings and base map support of SOI toposheets. Ground truth surveys also included radiometric reflectance observations of varied terrestrial features by Ground Truth Radiometer (GTR). The spectral reflectance curves thus obtained are presented in Fig 3(a), (b) and (c) which depict the reflectance behaviours of the prominent vegetation types, rock-outcrops and the waterbodies. This helped in understanding the spectral separability (Drury 1987) of the features to be interpreted from satellite imageries. Accurate mapping was made possible in short time and at less cost from satellite data. Analysis and interpretation of imageries included detection of tone/colour brightness followed by the classification of tonal colour groups. The spatial image analysis led to the establishment of relationships between these groups and the landform, drainage and cover patterns. This satellite imagery (FCC of bands 2, 3 and 4) showed waterbodies assume blue/deep blue colour according as the depths. Vegetation was observed in various shades of red depending on its health, density and related aspects. Soils showed brighter tone depending on the quartz content variations from place to place. Built-up area showed bluish tone/colour due to rocks and concrete. Other features were verified during the ground-checks.

Pre-field study comprised of satellite imagery interpretation on 1:50,000 scale, image studies and preliminary interpretations, plotting of different features and base map preparation. Subsequently, ground-truth survey was carried-out for cross checking of doubtful image features and extensive survey of the areas with shadow effects of the hills. Finally, from the inventories and maps thus prepared, areas under different classes were measured using digital planimeter. This helped in generating watershed land-use/land cover statistics. Map preparation was aided by the light table with co-ordinate measuring system and optical reflecting projector.

## RESULTS AND DISCUSSION

This study has led to the generation of following land-use classification in the watershed, the level I categories of which are: (1) Forest land (2) Agricultural land (3) Waste land (4) Built-up land and (5) Surface water bodies and its further sub-division has led to 13 sub-classes at level II. The spatial distribution pattern of the land-use/land cover classes for the year 1992 and 1988 are shown in Table 1. This table also depicts the % variation of the land-use under different classes over the years 1988 and 1992. The area distributions of the land-use classes in terms of change detection for the corresponding years are shown in Fig 4(a). The
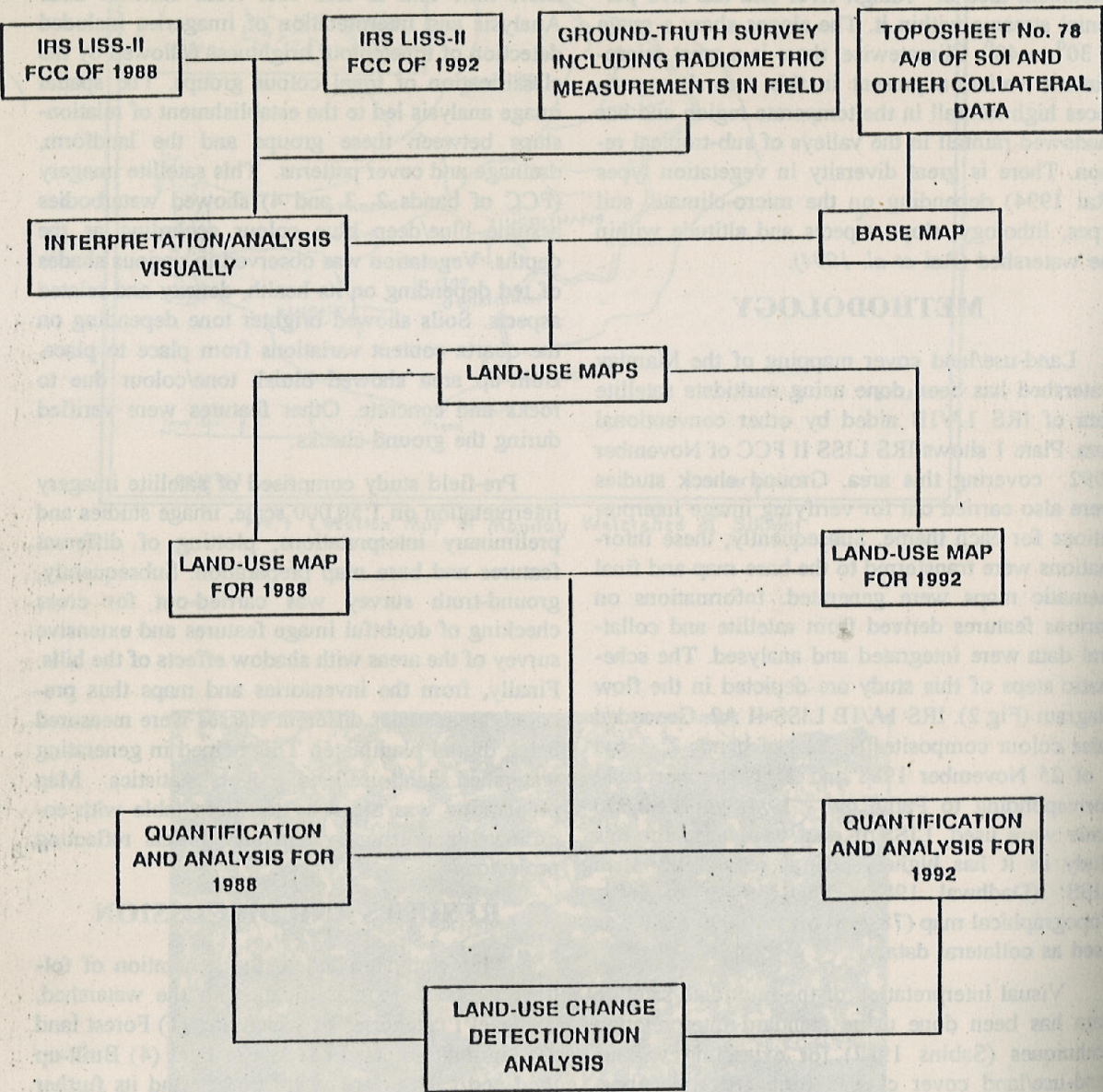
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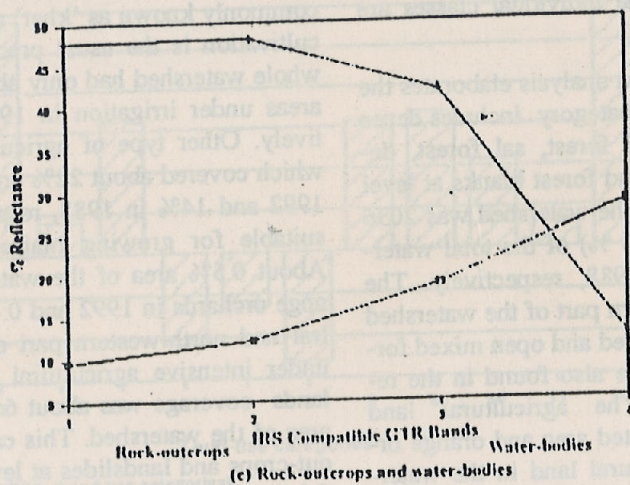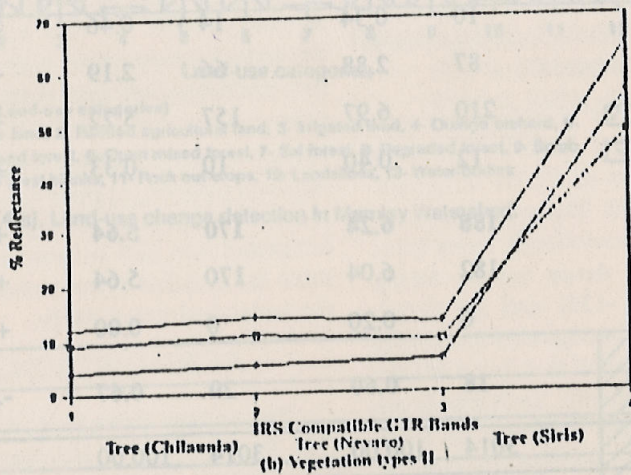Fig 2.  Flow diagram for land-use change detection of Mamlay watershed
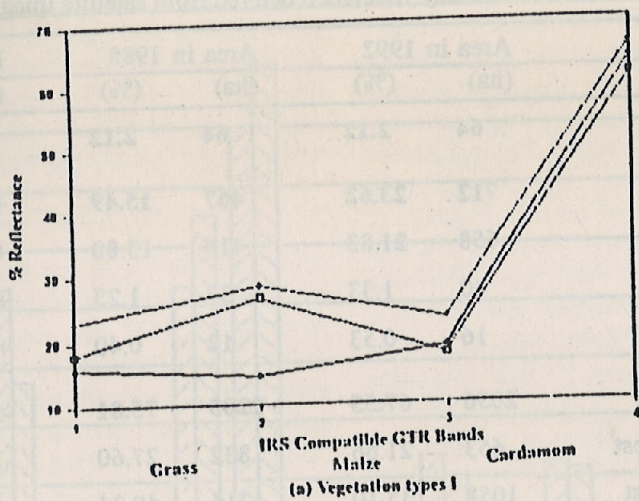
**Fig 3. Spectral reflectance curves for vegetation types, rock-outcrops and water-bodies of MamlayWatershed, South Sikkim**

Table 1.Changes in Land-use area of Mamlay watershed derived from satellite images

| Level/ S.No | Class | Area in 1992 (ha) | Area in 1992 (%) | Area in 1988 (ha) | Area in 1988 (%) | Diff. (+/—) | Var. (%) |
|---|---|---|---|---|---|---|---|
| I1 | **Built-up land** | 64 | 2.12 | 64 | 2.12 | 0 | 0.0 |
| I2 | **Agricult. land** | 712 | 23.62 | 467 | 15.49 | +245 | 52.5 |
| II2.1 | Rainfed land | 658 | 21.83 | 416 | 13.80 | +243 | 58.2 |
| II2.2 | Irrigated land | 40 | 1.33 | 37 | 1.23 | +3 | 8.13 |
| II2.3 | Orange Orchard | 16 | 0.53 | 12 | 0.40 | +4 | 32.50 |
| I3 | **Forest land** | 2036 | 67.55 | 2285 | 75.81 | -249 | -10.90 |
| II3.1 | Dense mixed forest | 653 | 21.66 | 832 | 27.60 | -179 | -21.52 |
| II3.2 | Open mixed forest | 1058 | 35.10 | 1216 | 40.34 | -158 | -12.98 |
| II3.3 | Sal forest | 10 | 0.34 | 14 | 0.46 | -4 | -26.09 |
| II3.4 | Degraded forest | 87 | 2.88 | 66 | 2.19 | +21 | 31.51 |
| II3.5 | Scrub land | 210 | 6.97 | 157 | 5.22 | +53 | 33.52 |
| II3.6 | Forest blanks | 12 | 0.40 | 10 | 0.33 | +2 | 21.21 |
| I4 | **Waste land** | 188 | 6.24 | 170 | 5.64 | +18 | 10.64 |
| II4.1 | Rock out-crops | 182 | 6.04 | 170 | 5.64 | +12 | 7.09 |
| II4.2 | Landslides | 6 | 0.20 | 0 | 0.00 | +6 | 100.00 |
| I5 | **Water bodies** | 18 | 0.60 | 20 | 0.67 | -2 | -10.45 |
| | Total | 3014 | 100.00 | 3014 | 100.00 | | |

percentage variation of the individual classes are presented in Fig 4(b).

This classification upon analysis elaborates the following: The forest land category includes dense mixed forest, open mixed forest, sal forest, degraded forest, scrub land and forest blanks at level II. The total forest land in the watershed was 2036 ha and 2285 ha (68 and 76 %) of the total watershed area in 1992 and 1988, respectively. The northern, western and eastern part of the watershed are dominated by dense mixed and open mixed forests. Some forest blanks are also found in the reserve forest category. The agricultural land includes rainfed area, irrigated area and orange orchards at level II. Agricultural land in the watershed varies from 24% in 1992 to 16% in 1988. There are two types of agricultural land found in this watershed. The low lands along the river bed commonly known as 'khet' are irrigated and paddy cultivation is the usual practice in this land. The whole watershed had only about 1.33% and 1.23% areas under irrigation in 1992 and 1988, respectively. Other type of agricultural land is rainfed, which covered about 22% area of the watershed in 1992 and 14% in 1988, respectively. This land is suitable for growing maize, ginger and pulses. About 0.5% area of the watershed was under orange orchards in 1992 and 0.4% in 1988. The central and north-western part of the watershed was under intensive agricultural practices. The waste lands coverage was about 6 and 5 % of the total area of the watershed. This category includes rock out-crops and landslides at level II. In 1992, about 6 ha area was under landslides whereas no landslides were observed in 1988. The built-up land as only cluster settlements of the watershed are in-
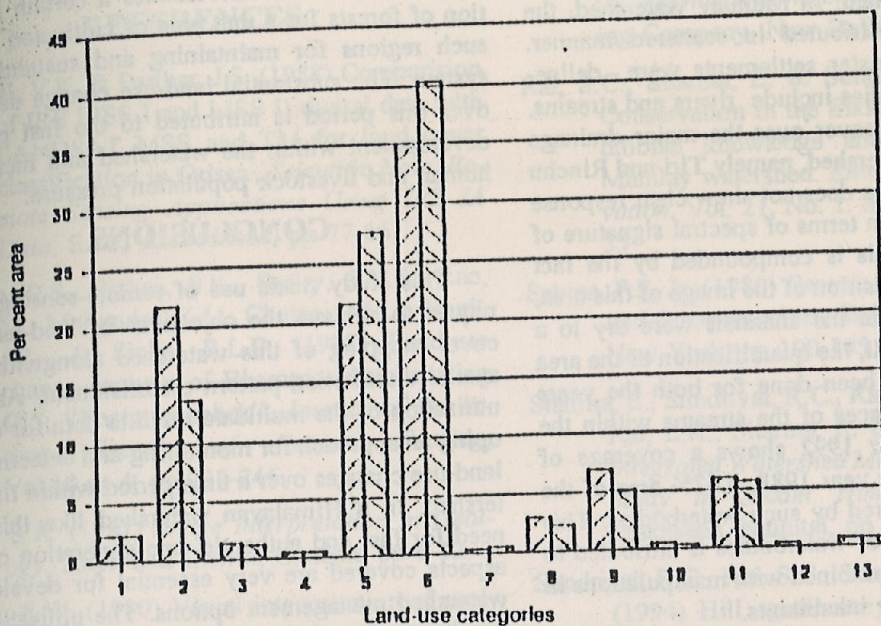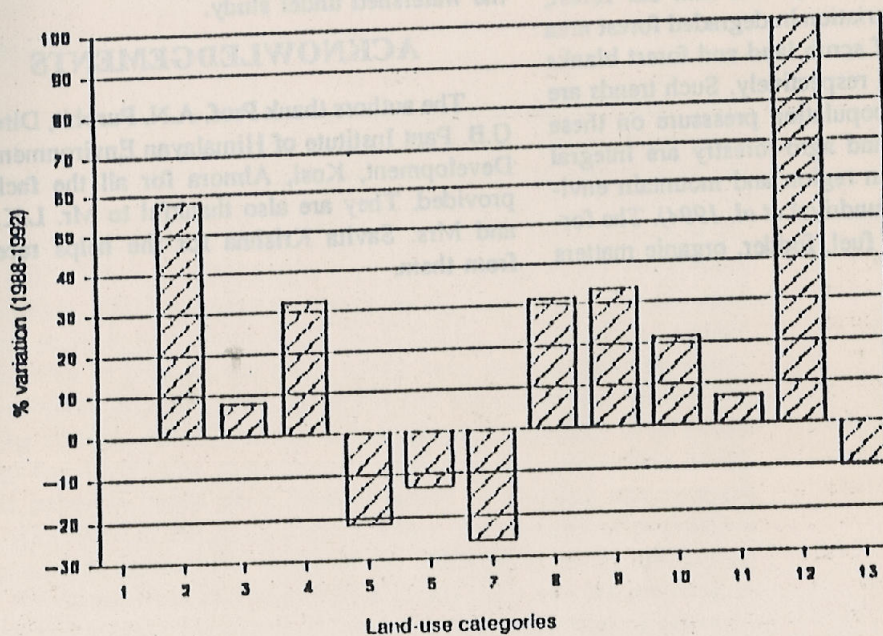
INDEX (Land-use categories)
1- Built-up land, 2- Rainfed agricultural land, 3- Irrigated land, 4- Orange orchard, 5-
Dense mixed forest, 6- Open mixed forest, 7- Sal forest, 8- Degraded forest, 9- Scrub
land, 10- Forest blanks, 11- Rock out-crops, 12- Landslides, 13- Water-bodies

☑ 1992
☒ 1988

Fig 4(a). Land-use change detection in Mamlay Watershed.



INDEX (Land-use categories)
1- Built-up land, 2- Rainfed agricultural land, 3- Irrigated land, 4- Orange orchard, 5-
Dense mixed forest, 6- Open mixed forest, 7- Sal forest, 8- Degraded forest, 9- Scrub
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Fig 4(b). Variation (%) in Land-use (1988-1992) of Mamlay watershed.

cluded in this class. This class covers about 2% area of the watershed. In Mamlay watershed, the settlements are distributed in scattered manner. Therefore, only cluster settlements were delineated. The water bodies include rivers and streams. Due to vegetation cover over the major drainage channels of the watershed, namely Tiri and Rinchu khola, satellite image does not show clear response for these channels in terms of spectral signature of the water body. This is compounded by the fact that during the acquisition of the image of this area, season was such that the channels were dry to a great extent. But, still, the quantification of the area of waterbodies has been done for both the years depending on the traces of the streams within the watershed. The year 1992 shows a coverage of 0.6% whereas in the year 1988, 0.67% area of the watershed was covered by such waterbodies. This change in the status of waterbodies is attributed to increasing farming combined with manipulations in small streams by the inhabitants.

Agricultural usage shows a positive variation which encroaches upon other land-use practices. This class shows a variation of 52.5% in agricultural area from 1988 to 1992. The waste-lands varied by 11 per cent. The variation in forest types observed are as follows: dense mixed forest, −21.5%, open mixed forest, −13% and sal forest, −26%. Whereas, the variation in degraded forest area is 31.5% and that of scrub land and forest blanks are 33.5 and 21.21%, respectively. Such trends are inferred due to the population presssure on these forests. Agriculture and agro-forestry are integral part of the Himalayan region and mountain environment in general (Sundriyal *et al. 1994)*. The forest is chief source of fuel, fodder, organic matters

and nutrients. This neccessiates a certain proportion of forests for a unit area of cultivated land in such regions for maintaining and sustaining the system. The substantial land-use change detection over this period is attributed to the fast pace of development within the watershed and increasing human and livestock population pressure.

## CONCLUSIONS

This study made use of remote-sensing techniques to achieve the objectives of land-use/land cover mapping of this watershed alongwith their spatial distribution pattern establishment. As also, utilisation of the multidate satellite data for developing an approach for monitoring and detecting the land-use changes over a time period within the watershed. In a Himalayan watershed like this, the need for fast and authentic data generation on the aspects covered are very essential for developing watershed management options. The utilisation of remote-sensing for such purposes is very well demonstrated by this study. The further scope of the study can be outlined as development of total management options for planned and systematic watershed development strategies where it can be integrated into GIS to provide watershed management information system after fully characterising the watershed under study.

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